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Natural Resource Stewardship and Science

Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2015 Annual Report

Natural Resource Report NPS/SEAN/NRR—2015/1076

ON THIS PAGE
A murrelet dives in Glacier Bay National Park
Photograph courtesy of Anne Schaefer

ON THE COVER
A marbled murrelet takes flight with a meal
Photograph courtesy of Anne Schaefer

Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2015 Annual Report

Natural Resource Report NPS/SEAN/NRR—2015/1076

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available in digital format from the Southeast Alaska Network website (http://science.nature.nps.gov/im/units/sean/KM_Main.aspx), and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Executive Summary

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance and spatial distribution of Kittlitz's (KIMU) and marbled murrelets (MAMU) in Glacier Bay National Park and Preserve, an important summer residence for both species. Monitoring program design focuses on KIMU, with secondary consideration of MAMU. The SEAN uses boat-based line transect surveys to estimate species-specific, on-water density and abundance of murrelets, accounting for detection probability and unidentified murrelets.

We surveyed 249.9 km on 46 transects from 9-16 July 2015 across the 1,170 km^2 survey area in Glacier Bay proper. We estimated an abundance of 10,778 KIMU (SE = 2,598) and 83,793 MAMU (SE = 12,044). Estimated KIMU abundance was slightly lower than the seven-year average of abundance estimates (11,255) and increased only 3% from 2014. Estimated MAMU abundance was the second highest on record and increased 102% from 2014. From 2009 to 2015, KIMU abundance estimates have ranged from 7,210 to 16,469 with annual changes of -56% to 120%, while MAMU have ranged from 28,978 to 84,428 (seven-year average = 60,959) with annual changes of -51% to 113%.

In 2016, the SEAN will synthesize existing abundance and trend information and re-examine field and analytic methods to assess if monitoring in its current form is likely to achieve program objectives. Our results demonstrate that key operational components of our monitoring protocol are functioning as intended.

The SEAN Kittlitz's Murrelets Resource Brief is a non-technical summary of recent monitoring program highlights and relevance to park management. It can be viewed and downloaded at:

http://science.nature.nps.gov/im/units/sean/auxrep/KM/KM_resource_brief.pdf

Acknowledgments

Since 2011, R. Sarwas has provided critical technical support for the NPTransect application. K. Nesvacil assisted with field surveys for the third year in a row, along with J. Barton and T. De Santo. The Glacier Bay National Park and Preserve Visitor Information Station oversaw boating logistics and safety while conducting surveys. Glacier Bay staff, especially L. Sharman, L. Etherington, and A. Banks, facilitated our research in the park.

Introduction

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance of Kittlitz's murrelets (*Brachyramphus brevirostris*, hereafter "KIMU") and marbled murrelets (*B. marmoratus*, hereafter "MAMU") in Glacier Bay National Park and Preserve. The program arose from concern over potential global and local population declines (Piatt et al. 2011, USFWS 2013, Kirchhoff et al. 2014) and the hypothesis that KIMU populations respond to fluctuations in components of the Glacier Bay marine and terrestrial ecosystems (Moynahan et al. 2008). As part of its Vital Signs Monitoring Program, the SEAN designated KIMU as a priority natural resource with the specific objectives of monitoring status and trends in abundance and spatial distributions.

The KIMU is a seabird endemic to Alaska and northeastern Russia, with the highest breeding population densities in the northern Gulf of Alaska (Day et al. 1999). KIMU in summer are often associated with tidewater glacier and glacial fjord habitats, but also occur in non-glacially influenced areas (Day et al. 1999, Arimitsu et al. 2011, Kissling et al. 2011, Madison et al. 2011). KIMU often forage in proximity to glacier outflows (Day and Nigro 2000, Kuletz et al. 2003) and nest in recently de-glaciated areas with sparse vegetation (Day 1995, Kissling et al 2015a). As a summer resident, open-water, pursuit forager, KIMU are likely to play an important role as integrators of variation in marine and terrestrial ecosystems and directly relate to the conceptual ecological models in the SEAN Vital Signs Monitoring Plan (Moynahan et al. 2008). Although the specific ecosystem linkages are unclear (USFWS 2013), KIMU use of glacially-influenced habitats link this species to dynamic physical habitat conditions such as glacial extent and oceanography that are subject to chronic climate-induced changes (Larsen et al. 2007).

SEAN monitoring focuses on estimating early July population abundance and trend primarily for KIMU and secondarily for MAMU. Several challenges inherent to Glacier Bay and its murrelet populations complicate estimating murrelet abundance: difficulty distinguishing between the two cryptic species, incomplete detection of murrelets along transects, large spatial and temporal variation in populations, and convoluted topography that complicates survey transect placement. The 2009 and 2010 annual KIMU reports, in conjunction with the final long-term monitoring protocol (Hoekman et al. 2013) fully describe monitoring methods developed to address these challenges.

These annual reports are designed to efficiently deliver data in a concise format, focusing on population abundance and spatial distributions. Periodic syntheses at six-year intervals will assess program performance and population trends; the first of these reports will be authored during 2016. Our 2015 study objectives were to complete the seventh year of boat-based line transect surveys, estimate population abundance of KIMU and MAMU in Glacier Bay, describe their spatial distribution, and summarize results since 2009.

Methods

This section includes a brief overview of survey design, survey methods, and analytic approach. Full details can be found in the SEAN long-term monitoring protocol (Hoekman et al. 2013); relevant protocol sections are referenced below.

Study area

Glacier Bay is a narrow, glacial fjord located in Southeast Alaska. The study area encompassed 1,170 km^2 of waters north of Icy Strait and excluded some areas designated as non-motorized waters or those that did not allow safe survey vessel passage (Figure 1).

See Chapter 1 of the SEAN long-term monitoring protocol (Hoekman et al. 2013) and Hoekman et al. (2011a) for more detail.

Survey design

We employed a generalized random tessellation stratified sampling design (GRTS; Stevens and Olsen 2004) to minimize deleterious effects of large spatial variation in murrelet abundance (Drew et al. 2008, Hoekman et al. 2011a,b) by providing a random, spatially-balanced sample. We allocated survey effort relative to expected densities of KIMU using unequal probability sampling (Stevens and Olsen 2004). To avoid placing transects parallel to the observed density gradient of murrelets (Drew et al. 2008, Kirchhoff 2011) and to provide representative coverage across water depths, we oriented linear transects perpendicular to the local prevailing shoreline. In more enclosed waters we used shore-to-shore zigzag transects to avoid undesirably short transects. Transects are sampled according to an augmented, serially alternating panel design (McDonald 2003), where one panel (set of transects) is sampled annually and three others are visited on a three-year rotation, with 2015 including the third panel.

See Chapter 2 and Appendix B of the long-term monitoring protocol for more detail (Hoekman et al. 2013).

Boat survey methods

We conducted boat-based line transect surveys (Buckland et al. 2001) at a speed of $\leq$10 km/h aboard the National Park Service R/V Fog Lark, an 8.5 m landing craft with a large front deck that provided a viewing height of approximately 3 m above the water line for two observers. For all groups (murrelets of one species class in a flock) initially located on the water, observers recorded group size, species class (KIMU, MAMU, or unidentified), and estimates of distance and angle in a straight line projecting forward from the bow of the boat. The allowable Beaufort sea state was $\leq$ 2. Program NPTransect (designed by R. Sarwas and W. Johnson, National Park Service) was used to record observations and associated GPS-based date/time/location stamps.

See the long-term monitoring protocol (Chapter 3 of the narrative, Standard Operating Procedures, hereafter “SOPs,” 1, 2, 3, and 9, and Appendix F) for more detail (Hoekman et al. 2013).

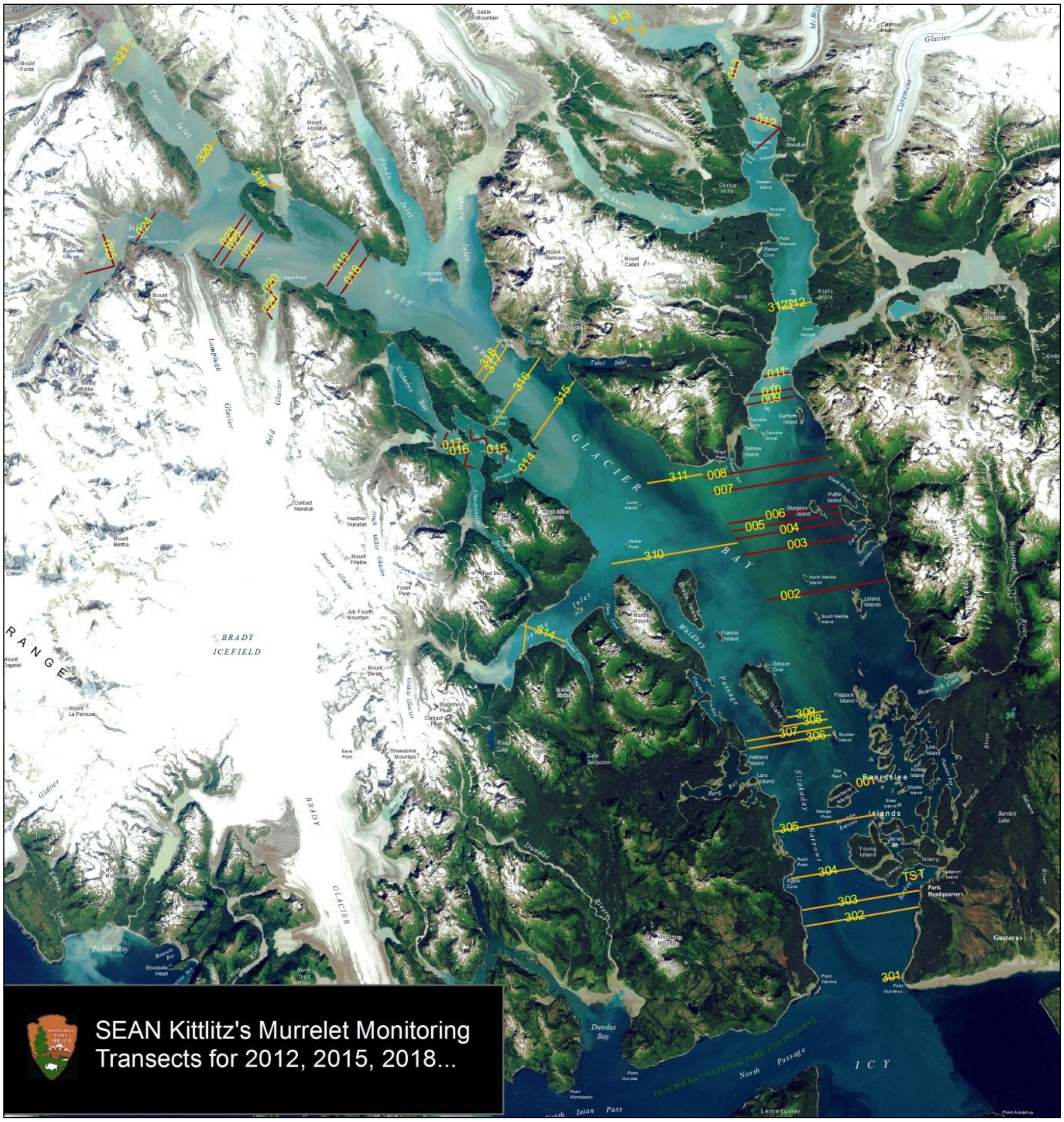

Figure 1. Line transects surveyed for murrelets in July 2015. Permanent (red lines) and Panel 3 (orange) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotation. Linear transects were used in open waters (>2.5 km wide) and zigzag transects were used in more restricted waters. Transects extended from shore to shore, except a few truncated at mid-Bay to maintain optimal transect length. Linear transects were oriented perpendicular to the prevailing shoreline. The orientation of zigzag transects relative to shore was determined by the width of each area.

Abundance estimation

We estimated detection probability and group size using Program DISTANCE version 6.2 (Thomas et al. 2010) and species-specific abundance using statistical software R version 3.1.0 (R Core Team 2014) following recommended distance sampling methods (Buckland et al. 2001) and protocol SOP 12 (Hoekman et al. 2013). We modified distance sampling methods to account for incomplete detection near the transect center line and unidentified murrelets. Adjustments for unidentified murrelets assumed correct species identification and identical proportions of each species in the identified and unidentified samples. Density estimates were based on several component parameters: detection probability across the transect width, detection probability near the center line, group size for each species class, and encounter rates for each species class. We estimated abundance by multiplying total study area (1,170 km^2) by estimated densities.

See Hoekman et al. (2011c) and the monitoring protocol (Appendices A and D, SOPs 11 and 12) for more detail.

Results

We surveyed 46 transects totaling 249.9 km from 9-16 July 2015 and recorded 1,748 on-water groups. All permanent and third-year panel transects were surveyed, including transect 024 in Johns Hopkins Inlet, which is sometimes blocked by ice (Figure 1). We classified 246 (14%) groups as KIMU, 1,119 (64%) as MAMU, and 383 (22%) as unidentified. Detection probability was modest (0.55; Table 1) within our selected 170 m right-truncation distance. Our estimated detection function declined moderately near the transect center line and showed a uniform, rapid decay at intermediate and longer distances (Figure 2), resulting in an estimated 94 m effective strip half-width (ESW). Thirty-nine percent of all observations were made during Beaufort sea state 0, 48% at 1, 12% at 2, and 1% greater than 2. Most observations (73%) were recorded during dry conditions with greater than 50% cloud cover, while 27% were recorded during rain, mist, or fog.

Higher average group size and encounter rates for MAMU (Table 1) resulted in estimates of on-water density and abundance nearly eight times higher than KIMU (Table 2). Precision of estimated abundance, measured as the coefficient of variation (CV, defined as the estimated standard error divided by the estimated abundance) was lower for KIMU (CV = 0.24; the third highest CV since 2009) than MAMU (CV = 0.14). Since 2009, estimated density and precision have varied considerably for each species (Figure 3). Estimated KIMU abundance was slightly lower than the seven-year average and increased only 3% from 2014 (Table 2). Estimated MAMU abundance was the second highest on record and increased 102% from 2014.

The highest KIMU densities were encountered in the Beardslee Entrance area, in the lower East Arm, near the Marble Islands, and in Reid Inlet. Otherwise, KIMU were scattered across the upper, east side of the main bay and the upper East and West arms. MAMU were present throughout the bay, but were especially dense in mid- and lower Glacier Bay regions (Figure 5) and least dense in the main channel of the West Arm. The relative spatial distribution of both species was similar to 2014, with the notable exception of higher density of KIMU in mid-bay in 2015.

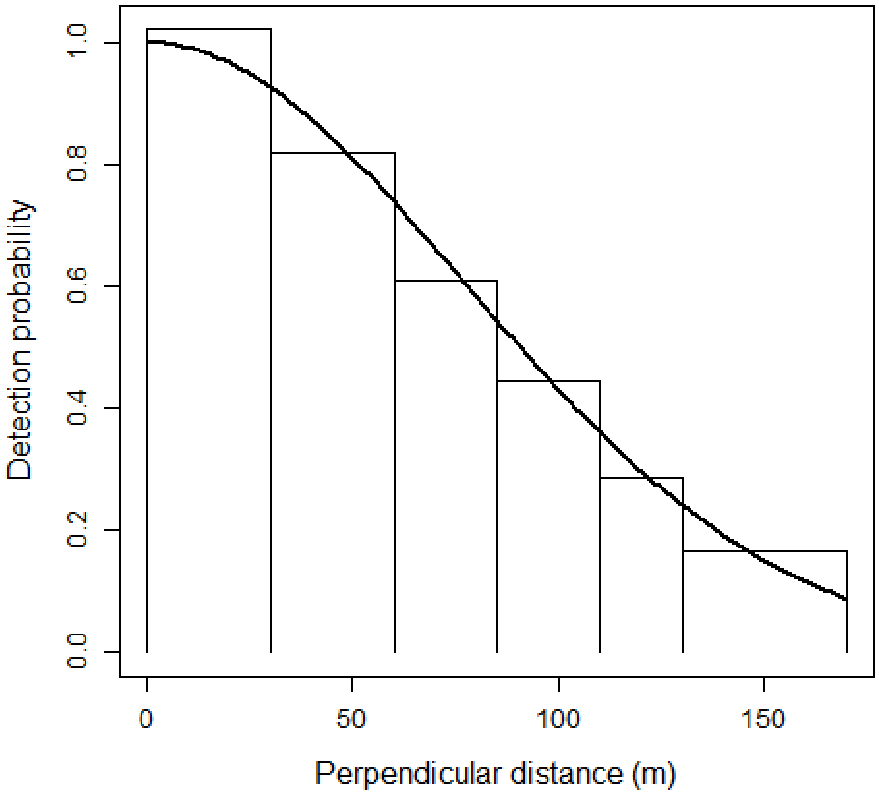

Figure 2. Estimated detection function for murrelets from line transect surveys in Glacier Bay, July 2015, illustrating estimated detection probability of murrelet groups relative to the perpendicular distances from the transect center line.

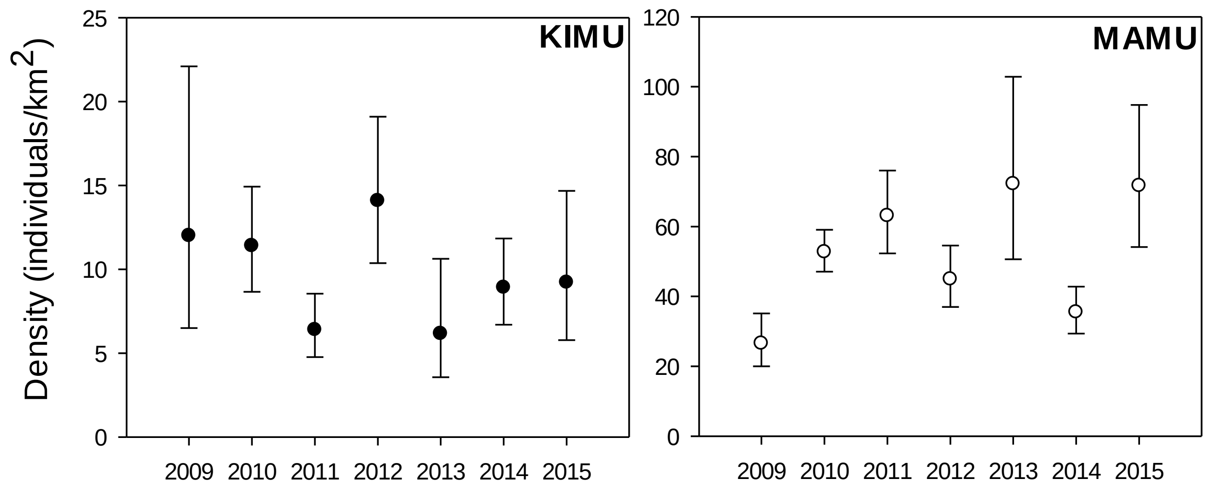

Figure 3. July densities (individuals/km^2) of Kittlitz's (KIMU, black circles) and marbled murrelets (MAMU, white circles) in Glacier Bay survey area from 2009-2015. Error bars are 95% confidence intervals. Note differing y-axis scales for density and that 2009 estimates were based on pilot survey methods (Hoekman 2011a). Densities are displayed to control for differences in survey area for 2009 (1,092 km^2) relative to 2010-2015 (1,170 km^2).

Table 1. Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay for July 2015. Group sizes were estimated as single averages for each species class (see SOP 11 of protocol for more detail).

Parameter	Estimate	SE	*P*-value	Degrees of freedom
Detection across transect width	0.55	0.01		1687
Detection near transect center line [a]	0.94	0.03		66
Group size: Average				
Kittlitz's murrelet [b]	1.74	0.07		241
Marbled murrelet	2.61	0.07		1103
Unidentified murrelet	3.03	0.24		340
Group size: Regression estimate				
Kittlitz's murrelet	1.68	0.05	0.18	240
Marbled murrelet [b]	2.37	0.05	< 0.001	1102
Unidentified murrelet [b]	2.18	0.10	< 0.001	339
Encounter rate (groups/km)				
Kittlitz's murrelet	0.73	0.18		44
Marbled murrelet	4.20	0.59		44
Unidentified murrelet	1.39	0.20		44

[a] Estimate from Hoekman et al. 2011c.

[b] Estimate selected for estimation of density and abundance.

Table 2. Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during July. Abundance was projected across surveyed waters only. Note that pilot surveys in 2009 differed in survey area (1,092 km^2) and methods (Hoekman et al. 2011a).

	Kittlitz's murrelet				Marbled murrelet			
Year	**Density**[a]	**SE**	**Abundance**	**SE**	**Density**[a]	**SE**	**Abundance**	**SE**
2015	9.2	2.2	10,778	2,598	71.6	10.3	83,793	12,044
2014	8.9	1.3	10,422	1,522	35.4	3.4	41,474	3,998
2013	6.2	1.7	7,210	2,046	72.2	13.2	84,428	15,394
2012	14.1	2.2	16,469	2,581	44.9	4.5	52,560	5,216
2011	6.4	1.0	7,477	1,119	63.1	6.0	73,766	7,055
2010	11.4	1.2	13,308	1,357	52.7	4.6	61,717	5,372
2009	12.0	3.7	13,124[b]	4,062	26.5	3.7	28,978[b]	4,077
All	**9.7**		**11,255**		**52.3**		**60,959**	

[a]Individuals/km^2

[b]Abundance extrapolated over 1,092 km^2 of sampled waters; all others extrapolated over 1,170 km^2.

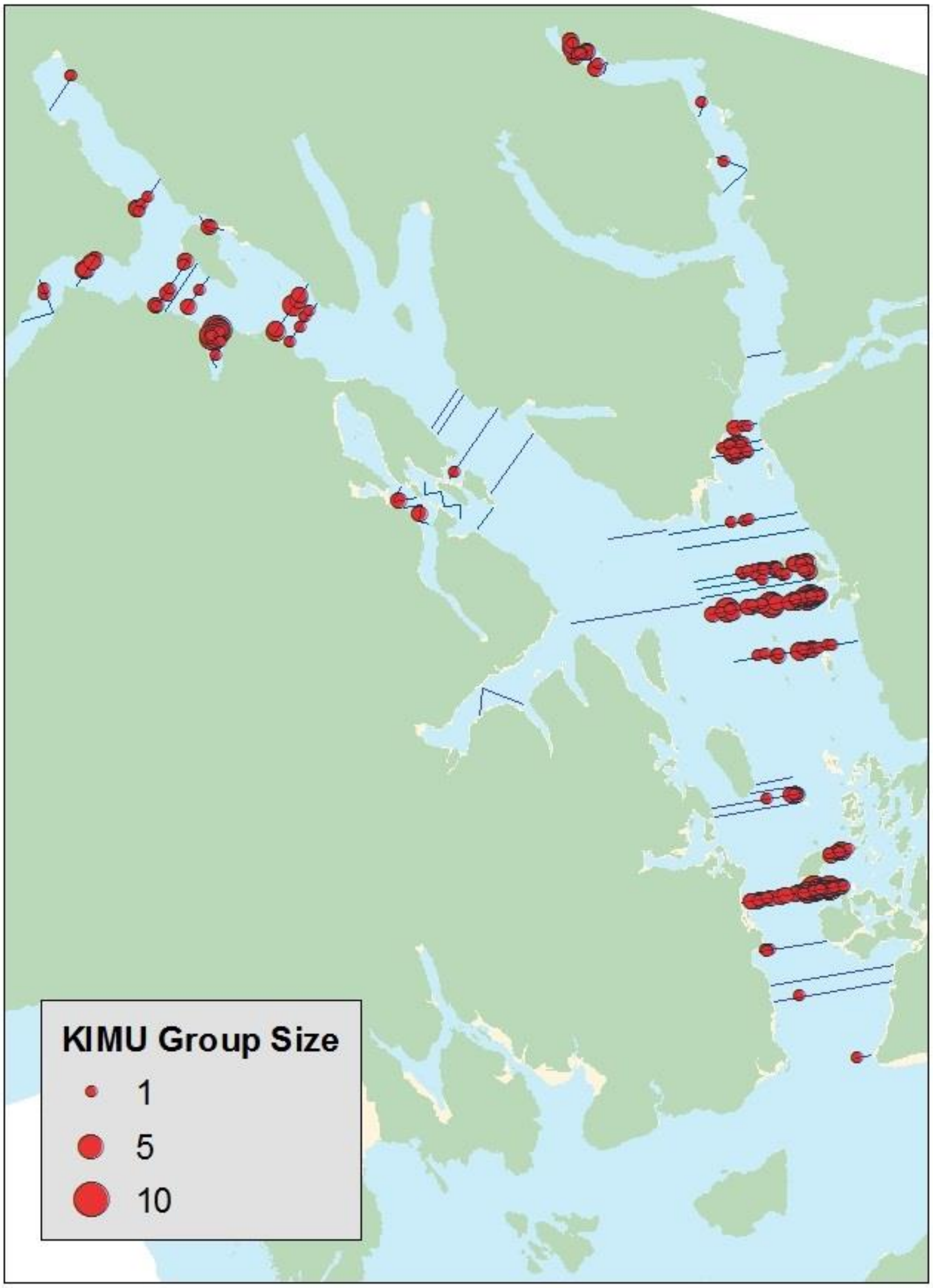

Figure 4. Spatial distribution of Kittlitz's murrelets observed during line transect surveys in Glacier Bay, July 2015. The area of circles is proportional to group size.

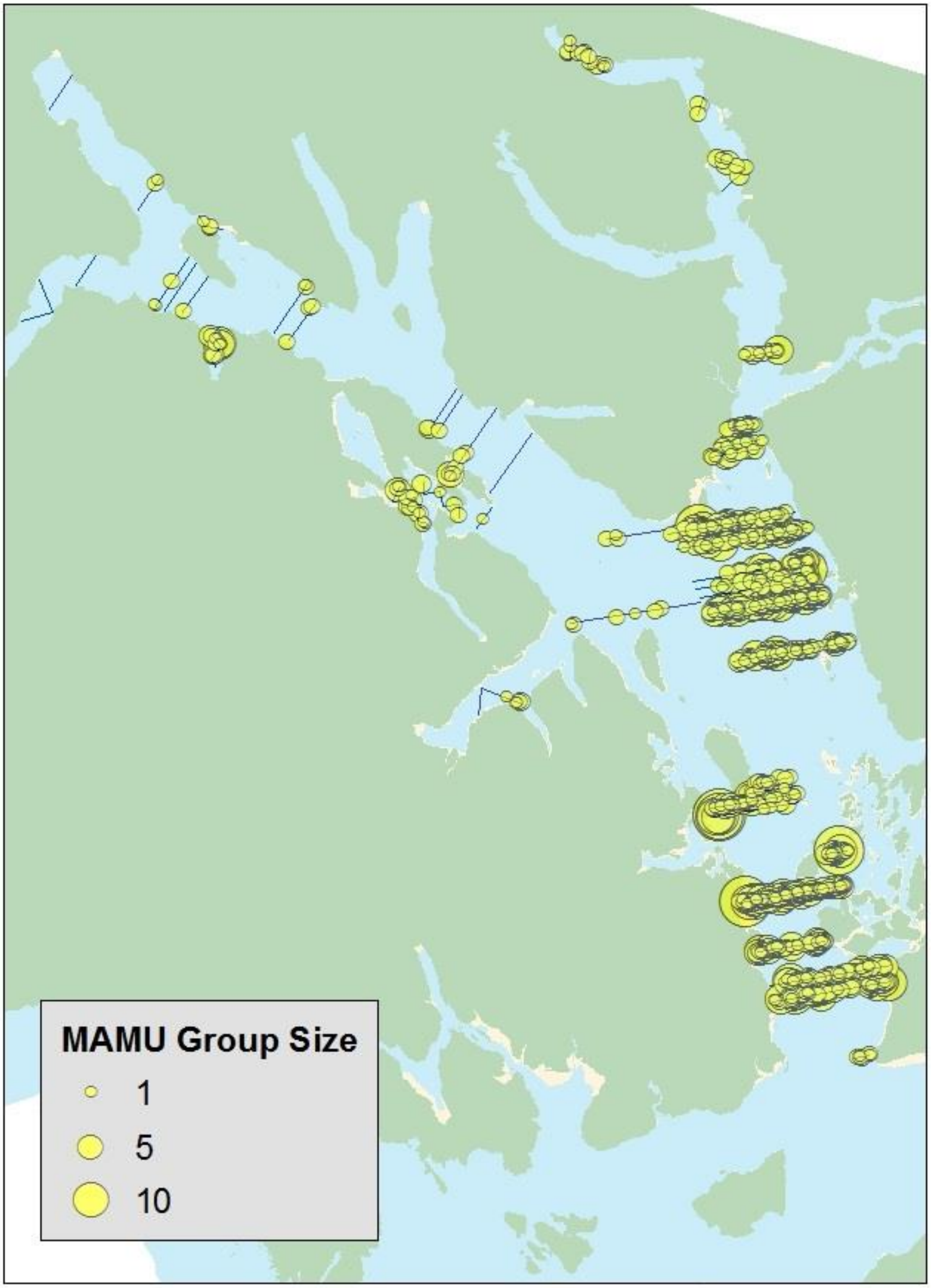

Figure 5. Spatial distribution of marbled murrelets observed during line transect surveys in Glacier Bay, July 2015. The area of circles is proportional to group size.

Discussion

Abundance estimates

Abundance estimates from 2009 to 2015 demonstrate that Glacier Bay's KIMU population continues to comprise an important fraction of the estimated minimum global population (USFWS 2013), but that MAMU have been much more abundant in Glacier Bay. For both species, our 2009-2015 abundance estimates generally have greatly exceeded previous estimates for Glacier Bay (Drew et al. 2008, Kirchhoff 2008, Kirchhoff et al. 2010), although this may in part reflect differences in survey methods and timing. For July 2010, our methods and results were similar to those of Kirchhoff and Lindell (2011). Among transect variation in encounter rates has dominated variance of abundance estimates, and the relatively patchy distribution of KIMU in 2015 drove decreased precision in abundance estimates (CV=0.24) relative to KIMU in 2014 and MAMU in 2015 (CVs=0.14).

Abundance estimates for both species have been highly variable across 2009-2015. Estimates for KIMU have ranged from 7,210 to 16,469 and from 28,978 to 84,428 for MAMU, with annual change ranging from about -50% to 120% for each. Changes between years usually appeared larger than could plausibly be attributed solely to intrinsic population growth given the life history of these species (Table 2; Piatt et al. 2007, USFWS 2013, Kissling et al. 2015a, b). Sampling variance and variable proportions of local populations within surveyed areas could contribute to annual change. In addition, large variation in breeding effort and low annual site fidelity observed for KIMU in nearby Icy Bay (Kissling et al. 2015a, b) suggest that immigration to and emigration from the local breeding population has contributed to annual change in abundance.

Detection and identification

Our estimated detection probability (0.55) and ESW (94 m) for 2015 were lower than for 2009-2014 surveys, indicating modest detection over a relatively narrow survey strip. Changes in survey procedures implemented in 2013 focused on reducing largely uninformative long distance observations and likely contributed to decreased ESW during 2013-2015 (mean = 112 m) relative to 2010-2012 (150 m). Additionally, 2014-2015 surveys had the highest proportions of observations recorded during precipitation or fog, which may also have contributed to decreased detection probability (mean=0.57) relative to 2010-2013 (0.71). Observers for 2015 surveys may also have been oversaturated by high total murrelet density, hence depressing detection.

Apart from lower samples of observations slightly decreasing precision of estimates, observed lower detection probabilities were not necessarily problematic, as robust detection functions can avoid bias in estimates if the critical assumption of nearly complete detection on the transect centerline is met. Thus, when poor visibility or task saturation reduce capacity of observers to detect and record observations, focusing efforts to assure recording of observations near the centerline is appropriate. But, moderately declining detection probability at 20-40 m distances in 2015 (Fig. 2) did not form an ideal "shoulder" (slope ~0) extending across the first two distance bins (Buckland et al. 2001), a divergence that can increase uncertainty in fitting an appropriate detection function. However, we concluded that our estimated detection function was reasonably robust (i.e., alternative viable detection functions altered abundance estimates by <5%) and that this steep decline likely resulted from "over-guarding" of the centerline by observers. See additional comments in Recommendations (below).

Classification of murrelet groups to species was the same as 2014 (78%) and slightly larger than the seven-year average (73%). From 2013-2015, species identification rates averaged 80%. The past three years, the SEAN has concentrated on improving identification training for observers before and during surveys. Based on experiments conducted in Glacier Bay during July 2013 (Schaefer et al. 2015) species identification error ranged from 1-5% and decreased with observer experience; ability to identify species increased with experience but declined with observation distance and Beaufort sea state. See additional comments in Recommendations (below).

KIMU spatial distribution

KIMU spatial distributions have shown considerable annual variation during our 2009-2015 (Figure 6) and prior 1999-2003 surveys (see Figure 8 in Drew et al. 2008), but some patterns persist. At broad spatial scales, KIMU have been most prevalent in small fjords and narrower (upper) portions of the West arm and in the east side of Glacier Bay, extending from the Beardslee Entrance area to the upper East arm. At finer scales, KIMU have often aggregated in recurring hotspots that have differed in location and intensity annually. Concentrations have been most consistent in Reid Inlet, while aggregations have been intermittent at other hotspots such as the Hugh Miller-Scidmore Complex (e.g., aggregations in 2000-2002, 2010-2013), Beardslee Entrance, near Russell Island, and the upper, east side of the main bay. Prior evidence closely linked breeding season populations of KIMU to tidewater glaciers, glacial outwash, and small glacial fjords (Kuletz et al. 2003, Arimitsu et al. 2011, Kissling et al. 2011). Reid Inlet has been the only tidewater glacier location where we have observed consistently high concentrations. While use of other glacially-influenced areas of the upper East and West arms has been high intermittently, use of some upper fjords with tidewater glaciers or glacial outwash has been moderate to low (e.g., Tarr, Wachusett, Johns Hopkins Inlets), and use of areas in the main bay without direct glacial influence has often been high. Recent observations of breeding season concentrations far from glacially-influence habitats suggest broader habitat affinities, and future assessments may benefit from considering additional hypotheses for explaining distributions, such as prey availability, gradients of temperature and salinity, bathymetry, tidal currents, and proximity to nesting habitat (Madison et al. 2011; Arimitsu et al. 2011, 2012; Drew et al. 2013; Kissling et al. 2015a).

Our sampling design seeks to maximize precision of KIMU population estimates by allocating sampling intensity in proportion to expected densities of KIMU (see Hoekman et al. 2013; Appendix B). In 2014 and 2015, KIMU encounter rates were slightly higher in strata with moderate rather than high expected densities, largely because of KIMU concentrations in the Beardslee Entrance. However, areas with low expected densities had low encounter rates. For 2011 through 2015 correspondence between expected densities and observed encounter rates has generally been good, indicating our allocation of effort has successfully increased sampling of areas with elevated KIMU densities.

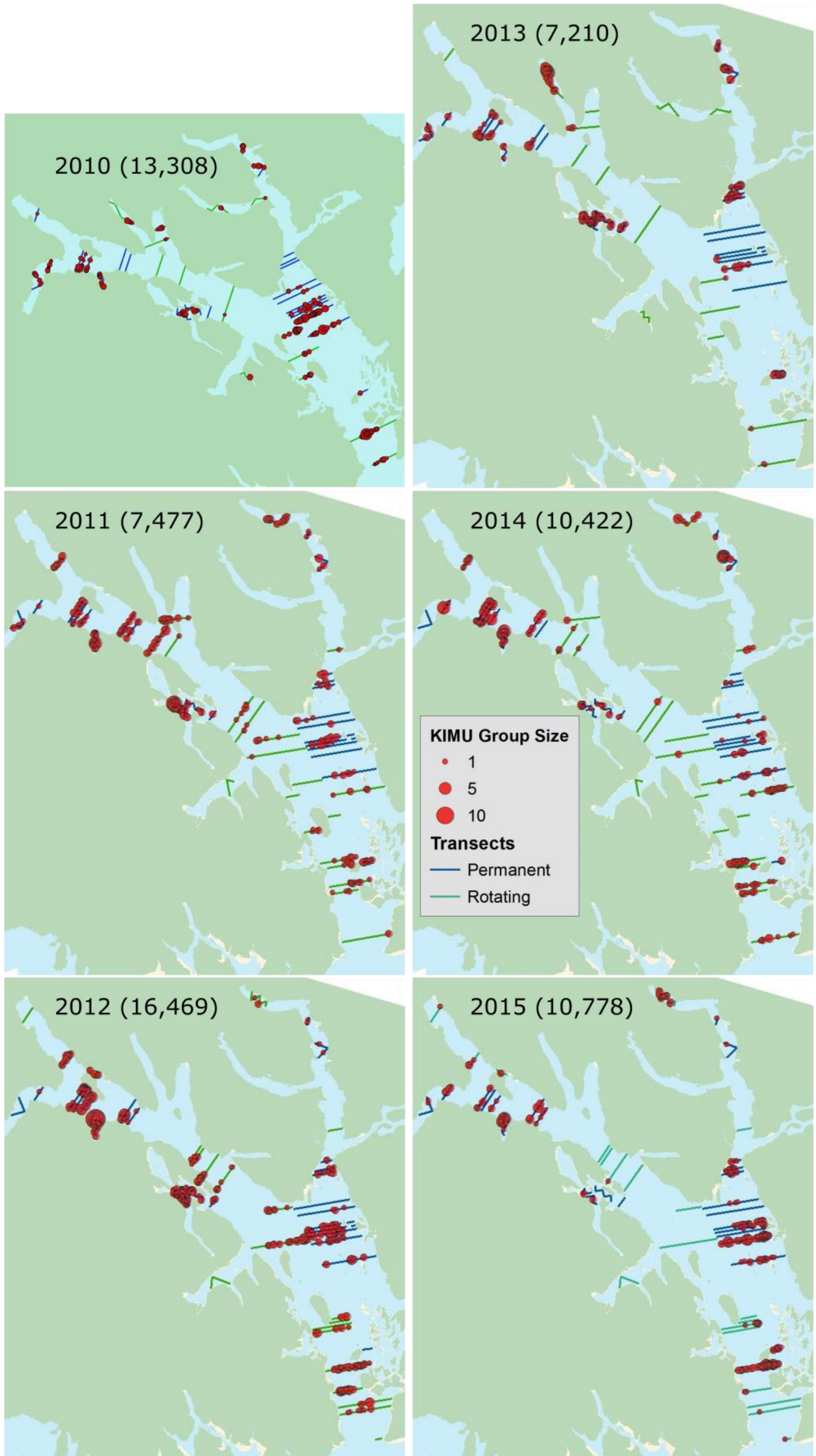

Figure 6. Comparison of KIMU spatial distributions from 2010-2015 in Glacier Bay. Maps are labeled with survey year and abundance estimate in parentheses. 2010 and 2013 represent Panel 1 of the three-year rotating panel design, 2011 and 2014 represent Panel 2, and 2012 and 2015 represent Panel 3. Permanent transects are blue, rotating transects green. Due to use of a different data collection tool, the 2010 map appears in a slightly different format.

Recommendations

During 2016, a synthesis report will assess population abundance and trend, performance of field and analytic methods (including implications of misidentified and unidentified murrelets and any necessary refinements to methods), and ability of the monitoring program to achieve its objectives. Although monitoring success depends in part on variability in murrelet populations within the survey area, our results and experience to date demonstrate that key operational components of our protocol are functioning as intended: equipment and personnel have been sufficient for timely completion of surveys; species identification rates have been adequate; procedures, hardware, and software for data collection have functioned well; detection probability has been sufficient and detection functions have been robust; and our methods for allocating survey effort have generally been successful in increasing sampling where KIMU density is high. To avoid “over-guarding” the transect centerline and facilitate a strong shoulder on detection functions, we recommend emphasizing that observers should focus highest search and recording effort on an over-lapping area ±40 m to each side of the transect centerline, especially when murrelet density is high. In addition to maximizing detection near the centerline, observers (especially those less experienced) should de-emphasize search effort at far distances from the transect line in order to reduce observations resulting in unidentified or misidentified murrelets.

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